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Performance Evaluation and Improvement Strategies: A Case Study of Lainchaur Intersection

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Abstract. Traffic congestion at many intersections in the Kathmandu Valley remains severe despite various traffic control and management measures, and the Lainchaur Intersection, a three-legged junction, is one of the most affected. The congestion is mainly due to uneven traffic distribution, vehicle composition, and the absence of signal control. This study evaluates the operational performance of the intersection using microscopic simulation in PTV VISSIM based on traffic data collected over four days in July. Peak-hour morning traffic data (9:00 AM-11:00 AM) were obtained through videographic surveys and observed traffic volumes were converted into Passenger Car Unit (PCU) in accordance with Nepal Road Standards (2070). The simulation was conducted for all four days, with three days used for calibration and one day for validation to ensure reliability and accuracy. Performance was assessed using queue length, vehicle delay, stop delay, and Level of Service (LOS). Results indicate severe congestion (LOS F) on major approaches, while minor movements operate under relatively better conditions (LOS A-C). As an improvement measure, fixed-time signal control based on the Webster method was evaluated under multiple cycle lengths (60 s, 80 s, 150 s, and 300 s), showing partial but inconsistent improvements. A future scenario with 7% annual growth indicates further deterioration, suggesting that fixed-time signal control alone may not be sufficient under future demand conditions, and adaptive or actuated signal control should be considered for improved operational efficiency.

Keywords: Level of Service, Microscopic simulation, Operational performance, Passenger Car Units, PTV VISSIM, Traffic congestion.

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1. INTRODUCTION

Urban intersections greatly influence the traffic performance of the road network because of their direct impact on traffic flow, travel time, and safety. The city of Kathmandu has witnessed a tremendous increase in both urbanization and vehicle ownership in recent times, which has increased traffic demand more than the supply, resulting in a number of intersections operating at high congestion levels. The traffic performance of an intersection is typically measured by delay, queue length, capacity, and level of service as defined by the Highway Capacity Manual. Intersections in Kathmandu, which lack proper traffic control and geometric design, often experience traffic delays and conflicts due to the improper assignment of traffic streams. The Lainchaur-Lazimpat-Kantipath intersection is one such important junction connecting most of the main roads in the valley and accommodating many private and commercial vehicles, but site observations reveal it faces high congestion with irregular traffic flow and queue spillbacks during peak hours. Congestion at the intersection is further contributed to by traffic discipline, a lack of priority to specific vehicle types, road markings, roadside development, and mixed traffic.

To address these issues, this study focuses on analyzing the traffic performance of the Lainchaur intersection, identifying traffic problems, and recommending possible improvements for effective road use. Due to the complexity of the intersection, the study utilizes the microscopic traffic simulation model PTV VISSIM to estimate traffic volume, delay, queue length, and level of service across the Lazimpat, Kantipath, and Lainchaur approaches to yield realistic results based on current conditions. The primary objective of the study is to assess the operational performance of the Lainchaur-Lazimpat-Kantipath intersection and suggest possible improvement strategies. Specific objectives include determining peak hour traffic volume, vehicle composition, and turning movement patterns on each approach; calibrating and validating the micro-simulation model to evaluate performance; assessing current operational conditions; and establishing probable alternatives to minimize congestion. Despite careful data collection and analysis, the study has certain limitations, as the analysis is based solely on morning peak hour traffic data without considering pedestrian movements or non-motorized vehicles, manual counting was used to extract volume from video graphic surveys, and the simulation results remain dependent on modeling assumptions and observed survey conditions.

2. LITERATURE REVIEW

Research in Nepal shows that most urban intersections are oversaturated during peak hours, which causes long wait times and a low LOS.

A study using SIDRA at the New Plaza Intersection found that traffic was very congested, with motorcycles making up most of the vehicles. Improving the timing of signals and the shape of the roads made difference in performance including average delay and queue length [1]. Another study at the Prithivi Chowk Intersection using HCM methods found that just optimizing the signals wasn't enough to yield better performance and thus increase in number of lanes was suggested [2]. PTV VISSIM was utilized at the New Baneshwor Intersection to show that changing the timing of traffic signals can make traffic safer and reduce conflicts [3]. Similarly, SIDRA is used to evaluate intersections in Satdobato Intersection [4], indicating significant delays and a Level of Service (LOS) rating of F under current circumstances, with enhancements realized via signal and geometric alterations.

The study in [5], [6], [7], [8] emphasized the importance of calibrating VISSIM parameters to reflect Kathmandu's heterogeneous traffic conditions. It shows that default simulation parameters are inadequate and that proper calibration significantly enhances simulation accuracy. A study in [9] used PTV VISSIM to evaluate traffic operations at the Kamrej intersection in India and reported an improvement in LOS from F to C through geometric enhancements and optimized signal control. Additionally, [10] applied HCM and HCS methods and found that grade separated intersections significantly reduce delay and improve LOS.

Studies that use simulations as in [11] show that optimizing signal timing lowers average delay during both peak and off-peak times. Also, [12] emphasized the significance of field-measured delay for precise Level of Service (LOS) estimation at signalized intersection.
Overall, studies carried out till the date shows that microsimulation models such as PTV VISSIM proved effective in capturing the complexities of microscopic traffic interactions, thus enabling accurate assessment of traffic performance at the intersection. It is proved that optimized traffic signal and geometry result in significant reductions in delay and improvement in the level of service.

2.1. **Research Gap.** A review of international and national studies indicates that microscopic simulation models such as PTV VISSIM can be effectively used to evaluate the performance of intersections under real traffic conditions.
Intersection studies in Nepal are mostly analytical using SIDRA and HCM while calibration of behavioural model parameters for mixed traffic conditions is rarely undertaken. In addition, analysis of the Lainchaur-Lazimpat-Kantipath intersection using calibrated microscopic traffic model has not been done yet. Therefore, this study attempts to develop a calibrated model to analyse the performance of the intersection using PTV VISSIM and propose alternative signal timings for different traffic scenarios.

3. METHODOLOGY

3.1. **Study Area.** The intersection study area was at the Lainchaur-Kantipath-Lazimpat intersection in the Kathmandu Valley, which connects commercial, institutional and residential areas. The study area comprises three highly active signalized road intersections.

FIGURE 1. Satellite Image of Lainchaur Intersection

The Lainchaur Intersection is close to the central campus (27.7086° N, 85.3170° E) with a high number of mixed modes of transportation such as private cars, buses, motorcycles, and pedestrians, seen in Figure 1. The Kantipath Intersection is the main road connecting the central business district and south Kathmandu (27.7061° N, 85.3235° E) with high traffic volume and extreme congestion during peak hours. The Lazimpat Intersection connects the commercial offices and diplomatic areas (27.7174° N, 85.3265° E) with many pedestrians and conflicts between different modes of transportation.

3.2. **Data Collection.** The data used for this study was obtained from both primary and secondary sources to ensure the accuracy and reliability of the traffic model. Primary data was collected from video traffic counts. In this case, videos provided by Metropolitan traffic office were used to collect traffic volume, turning movement, and vehicle classification. The data used were collected during the morning peak hour, from 9:00 AM to 11:00 AM. Video images were also used to determine signal timing.

Table 1. Passenger Car Unit (PCU) Conversion Factors Adopted from NRS 2070

Vehicle Type	PCU Factor
Bike	0.5
Car/Pickup/Micro/Tempo	1
Mini Truck	1.5
Bus/Truck	3

On the other hand, secondary data used included geometric data of the intersections, PCU values of Nepal Road Standard 2070 [13] and values of capacity from Nepal Urban Road Standard 2076 [14], satellite images, and relevant published literature. PCU conversion factors were used to handle varying traffic conditions and to convert observed traffic volumes into equivalent passenger car units, as shown in Table 1.

4. SIMULATION IN PTV VISSIM

4.1. 4.1 Signal Phasing and Movement Diagram.

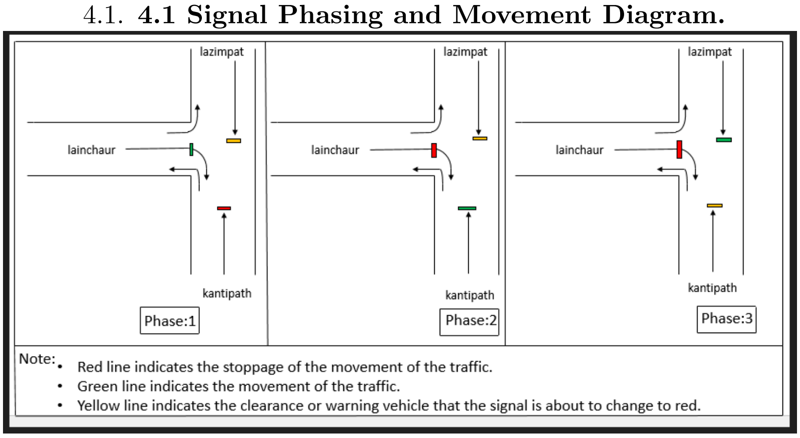

Figure 2. Existing Signal Movement Diagram of Lainchaur Intersection

The existing signal control at the Lainchaur Intersection was developed in PTV VISSIM using signal groups and movements as shown in Figure 2. A signal movement diagram was developed based on the field observation to capture the permitted and protected movements of the traffic streams for each signal stage. This would ensure that the VISSIM signal control was reflective of the actual traffic controls at the intersection.

4.2. **Development of Model in VISSIM.**

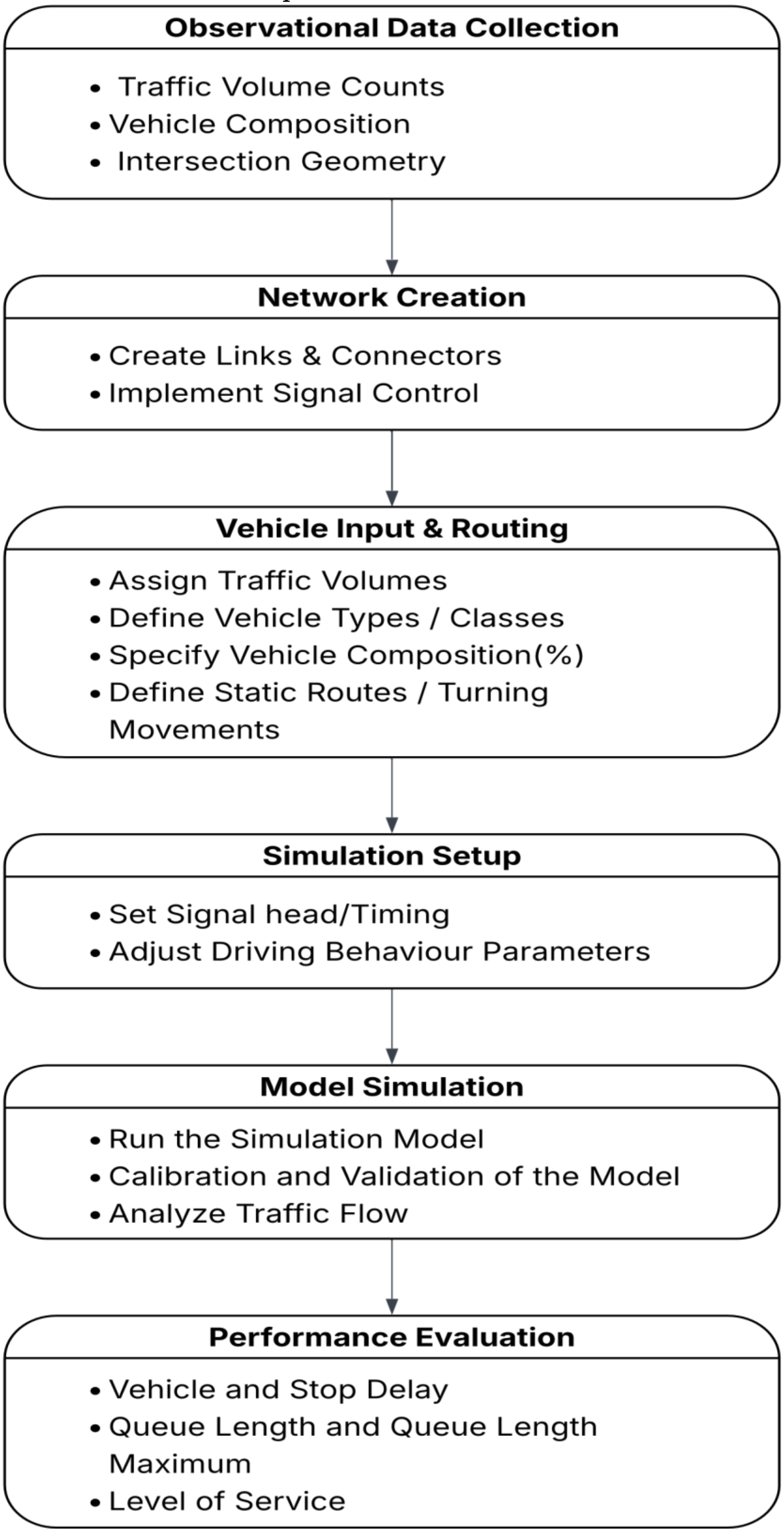

Figure 3. Flowchart of simulation model development in PTV VISSIM

The simulation model was developed in PTV VISSIM following a structured workflow, including network coding, input data integration, traffic volume assignment, and model configuration. The overall modelling procedure is illustrated in Figure 3.

5. MODEL CALIBRATION AND VALIDATION

5.1. **Calibration of VISSIM Model.** The calibration process was carried out in this study as illustrated in Figure 4.

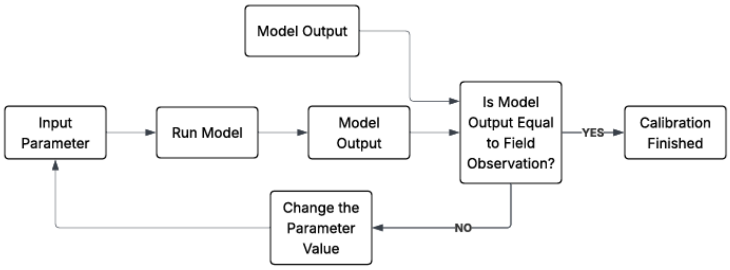

FIGURE 4. Flowchart of VISSIM Model Calibration Process

Driving behavior parameters in VISSIM were modified to perform calibration process. The sensitive calibration parameters, default values and calibrated values are presented in Table 2.

TABLE 2. Calibrated Driving Behaviour Parameters in PTV VISSIM

S.N	Sensitive calibration parameters	Default values	Calibrated values
1	Minimum look ahead distance	0m	5m
2	Minimum look back distance	0m	5m
3	Maximum look ahead distance	250m	150m
4	Maximum look back distance	150m	100m
5	Standstill distance for static obstacle	0.5m	0.1m
6	Average standstill distance	2m	0.1m
7	Additive part of safety distance	2	0.1
8	Multiplicative part of safety distance	3	0
9	Lane change duration distribution	-	0.5s
10	Minimum clearance (front/rear)	0.5m	0.1m
11	Minimum lateral distance (standing) at o km/h	0.2m	0.1m
12	Minimum lateral distance(driving)	1m	0.2m
13	Reaction time distribution	-	2-4s
14	Temporary lack of attention during flowing	-	2s
15	Distraction	-	1.5s
16	Desired Position at Freeflow	middle of lane	Left
17	Behaviour at red/amber signal	Go (same as green)	Stop (same as red)

Calibration of the VISSIM model was performed using traffic data from three days (Day 1, Day 2, and Day 3) by comparing field-observed and simulated traffic volumes, as illustrated in Figure 5.
Figure 5. Relationship between Observed Field Traffic Volume and Simulated VISSIM Traffic Volume During Calibration

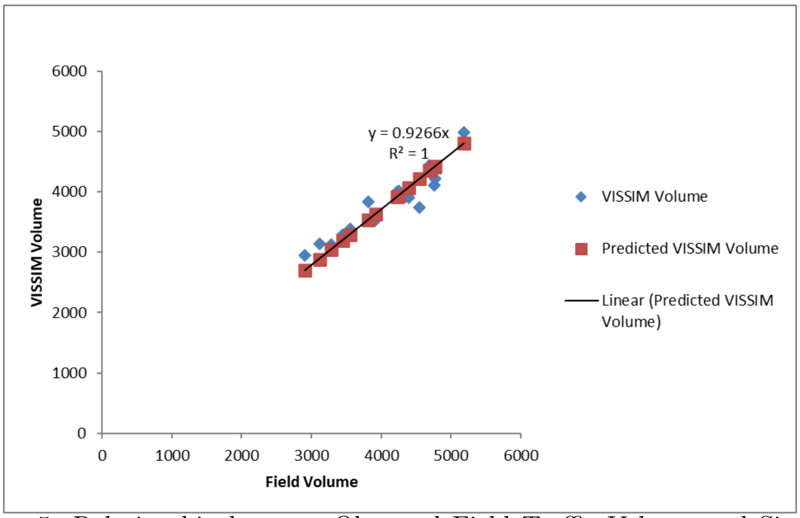

FIGURE 5. Relationship between Observed Field Traffic Volume and Simulated VISSIM Traffic Volume During Calibration

The R^2 value obtained after calibration was 0.9968, indicating that 99.68% of the variation in field traffic volumes is explained by the simulated model outputs. Regression equation obtained is presented in Equation (i).

$$VISSIMVolume = 0.9266 * FieldVolume..............(i) \qquad (1)$$

5.2. **5.2 Validation of VISSIM.** Model

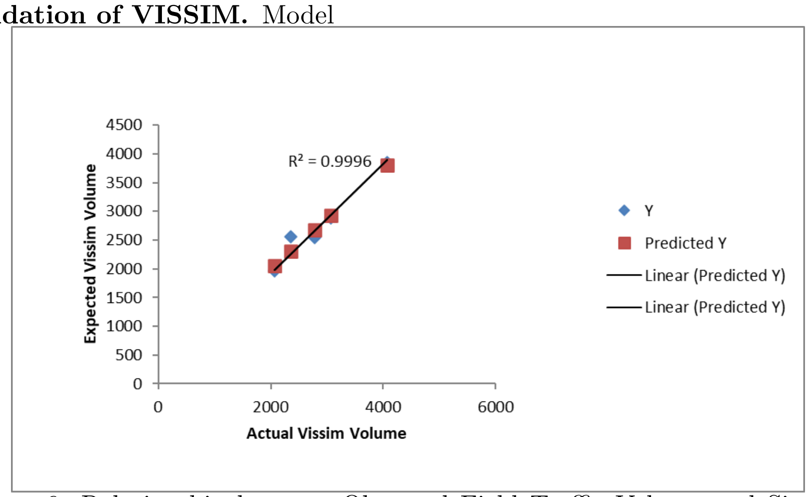

FIGURE 6. Relationship between Observed Field Traffic Volume and Simulated VISSIM Traffic Volume During Validation

The calibrated model was validated using traffic data collected on two separate days, which were not used during model development. The simulated results showed close agreement with observed field data, confirming the model's reliability for further analysis, as shown in Figure 6.
Figure 6. Relationship between Observed Field Traffic Volume and Simulated VISSIM Traffic Volume During Validation

6. DATA ANALYSIS

6.1. **Traffic Volume.** On the 22 , 23 , 24 and 25 of July, traffic volume surveys were conducted at the Lainchaur junction during the morning hours (between 9 am and 11 am) in order to analyze traffic demand and peak hour characteristics. From the conducted survey, it was found that demand varied greatly on different days of the survey. However, the peak hours were found to be consistent on all days of the survey and occurred between 9:15 am and 10:30 am. Movements originating and terminating at Kantipath were found to contribute the highest traffic demand, establishing Kantipath as the preferred route to Lainchaur junction (Figure 7).

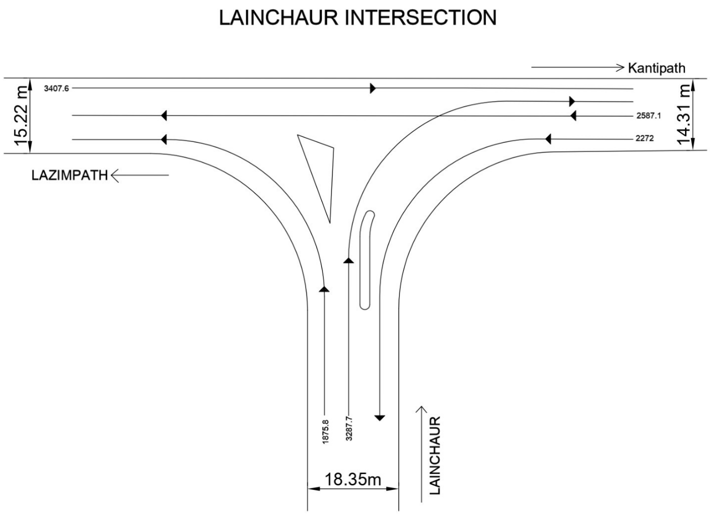

Figure 7. Traffic Volume Distribution at the Lainchaur–Lazimpat–Kantipath

A similar trend was observed on 23rd July, where the highest traffic demand occurred on the movement from Lainchaur to Kantipath, registering 4,758 vehicles (3,377 PCU). The second highest movement was observed on the movement from Lazimpat to Kantipath with a traffic volume of 4,551 vehicles (3,239 PCU). Traffic movements recorded on 23rd July were: 4,247 vehicles (2,872.5 PCU) from Kantipath to Lazimpat 3,453 vehicles (2,557.5 PCU) from Kantipath to Lainchaur, and 3,115 vehicles (1,836 PCU) from Lainchaur to Lazimpat.
On 24th July, the highest traffic volume was recorded from Lazimpat to Kantipath with a total of 4,695 vehicles (3,327.5 PCU). The second highest traffic volume was recorded on movements from Lainchaur to Kantipath with 4,769 vehicles (3,192 PCU). Traffic movements registered on 24th July were: 4,390 vehicles (2,943 PCU) from Kantipath to Lazimpat, 3,550 vehicles (2,750 PCU) from Kantipath to Lainchaur, and 2,910 vehicles (1,694.5 PCU) from Lainchaur to Lazimpat.
The highest traffic volume was recorded on the movement from Lainchaur to Kantipath on 25th July with 4,147 vehicles (2,800 PCU). Traffic movement from Lazimpat to Kantipath registered the second highest volume with a total of 3,1116 vehicles (3,997.5 PCU). Traffic movements recorded on 25th July were: 2,755 vehicles (1850.0 PCU) from Kantipath to Lazimpat, 2,115 vehicles (1,513.5 PCU) from Kantipath to Lainchaur, and 2,747 vehicles (1,689.5 PCU) from Lainchaur to Lazimpat.
Figure 7. Traffic Volume Distribution at the Lainchaur–Lazimpat–Kantipath

6.2. **Vehicle Composition.** Vehicle composition demonstrates the percentage of different vehicle types in traffic. It reflects to people for understanding the diverse character of road movement, analyzing flow and microscopic simulation modeling. Regarding the survey conducted at the Lainchaur, Lazimpat, and Kantipath intersection, it was categories into motorcycles, cars, pickups, microbuses, buses, trucks and tempos. It has been claimed that motorcycles are the most common type because they represent approximately 75% of the total flow. Car account for about 20.35%. Buses comprise around 3%, while microbuses 1.1%, pickups 0.45%, trucks 0.2% and tempos possess a tiny portion. To define vehicle types and their distribution, the vehicle composition was directly added into VISSIM model, as shown in Figure 8.

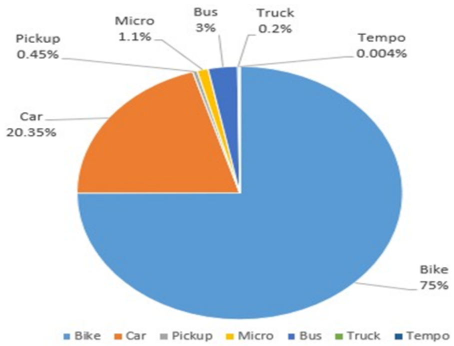

FIGURE 8. Average Vehicle Composition at the Intersection

6.3. **Evaluation of Intersection's Current Performance at Present.** It was found that the Lainchaur-Lazimpat and Kantipath-Lainchaur movements worked with level of service A having the minimum delay of 4.09 seconds and 3.08 seconds with zero queue length, respectively. However, the Lainchaur-Kantipath and Kantipath-Lazimpat movements operated on a level of service F characterized by very high delay (> 98 seconds) and long queues (up to 193.55 meters) causing traffic congestion and creating a bottleneck in the intersection. The Lazimpat-Kantipath movement had a moderate delay of 40.2 seconds, 32.47 meters of queue length, and a level of service C, implying that it was under moderate traffic flow. It can be concluded that this intersection requires improvements due to the delay and congestion in some of the movements as shown in Table 3.

TABLE 3. Operational Performance of Lainchaur Intersection Under Existing Traffic Conditions

	DIRECTIONS				
OUTPUTS	**Lainchaur to Lazimpat**	**Lainchaur to Kantipath**	**Lazimpat to Kantipath**	**Kantipath to Lainchaur**	**Kantipath to Lazimpat**
Qlen	0	89.93	32.47	0	75.02
Qlenmax	0	193.55	86.23	0	148.09
LOS	A	F	C	A	F
Vdelay	4.09	98.06	40.2	3.08	101.04
Stopdelay	0.26	56.15	23.46	0	61.3

TABLE 4. Operational Performance of Lainchaur Intersection Under Existing Traffic Conditions

			DIRECTIONS	
OUTPUTS	**Lainchaur to Lazimpat**	**Lainchaur to Kantipath**	**Lazimpat to Kantipath**	**Kantipath to Lainch**
Qlen	0	89.93	32.47	0
Qlenmax	0	193.55	86.23	0
LOS	A	F	C	A
Vdelay	4.09	98.06	40.2	3.08
Stopdelay	0.26	56.15	23.46	0

7. PERFORMANCE EVALUATION UNDER ALTERNATIVE SIGNAL TIMING

A fixed-time signal control system was developed for Lainchaur Intersection, where traffic is currently controlled manually, to examine its performance. The Webster method was used to estimate the optimum cycle length for a twophase signal system. Four cycle lengths—60 s, 80 s, 150 s, and 300 s—were tested in VISSIM. Traffic volume, queue length, maximum queue length, stop delay, and vehicle delay were used to compare the different cases. Traffic demand on July 22–24 was fairly consistent, although Day 2 had slightly higher volumes. Changing the signal timing affected the operation of the intersection rather than the traffic demand itself. Day 2 also produced the maximum queue length, indicating oversaturated conditions. The maximum queue results show that the 150 s cycle reduced extreme queue formation, whereas the 300 s cycle increased peak queues, especially for minor movements. Overall, the intermediate cycle lengths performed better than the shorter and longer cycles.

The revised signal cycles, particularly the 150 s cycle, reduced queues on Days 1 and 3. The 300 s cycle increased maximum queues. Average vehicle delay was highest under the base condition, while Day 2 showed the largest improvement after changing the cycle length. Stop delay also decreased with the 80 s and 150 s cycles, especially on Day 2. The 300 s cycle, however, increased delay on some approaches.

Figure 9 shows that the tested signal cycles generally reduced average queue lengths compared with the base condition. The 150 s cycle gave the best overall result, with the largest improvement on Day 2, which had higher initial congestion. Day 3 had the lowest queues, while the 300 s cycle slightly increased queues for minor movements.

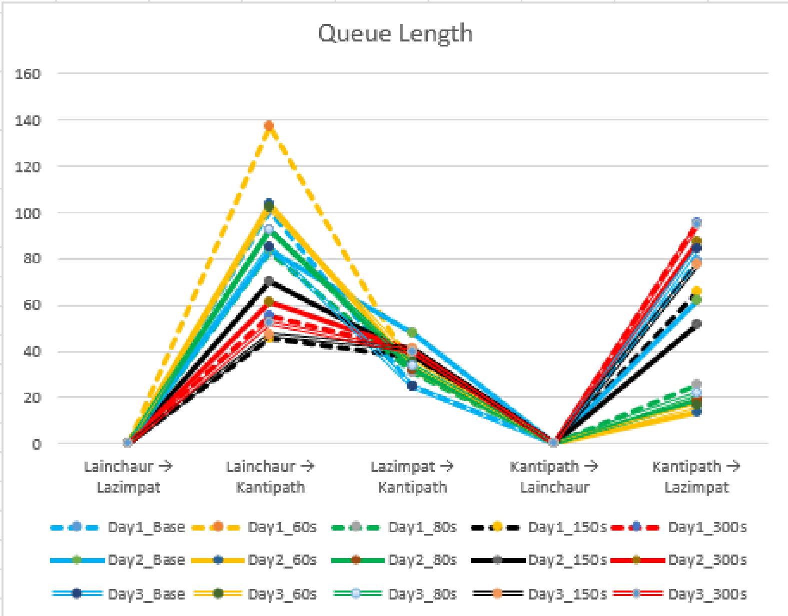

FIGURE 9. Average Vehicle Composition at the Intersection

Figures indicate that Level of Service (LOS) improves with optimized signal cycle times, following delay-based trends (Figure 10-12). The base condition exhibits poorer service during the peak period because of higher congestion and longer delays. The 150 s cycle generally gives the best performance among the tested cycles. The improvement is more noticeable when traffic demand is high. In comparison, the 300 s cycle can reduce performance on some movements because of longer waiting times.

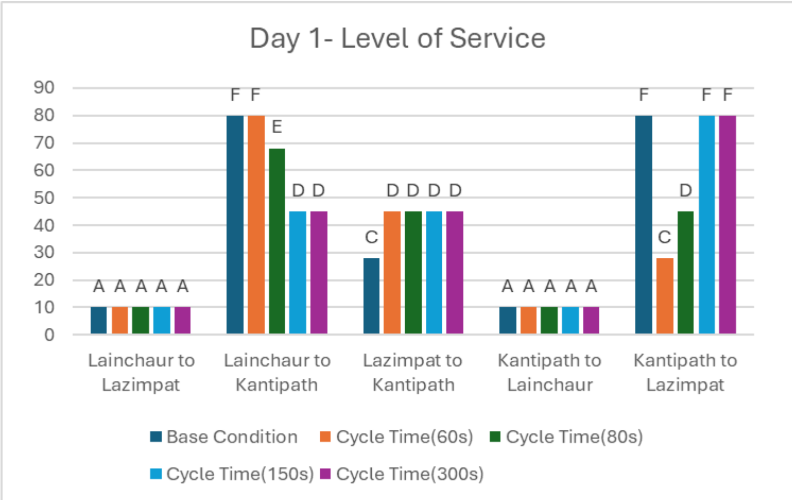

FIGURE 10. Level of Service Comparison under Different Signal Cycle Time Scenarios (Day 1)

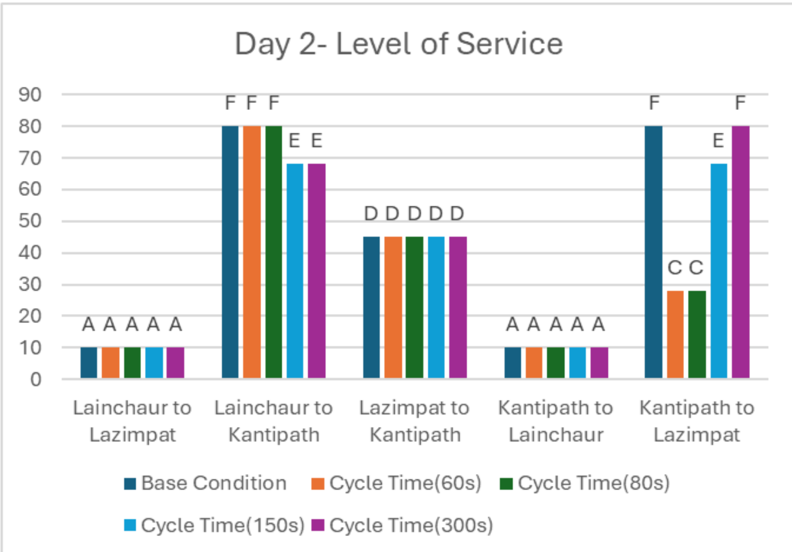

FIGURE 11. Level of Service Comparison under Different Signal Cycle Time Scenarios (Day 2)

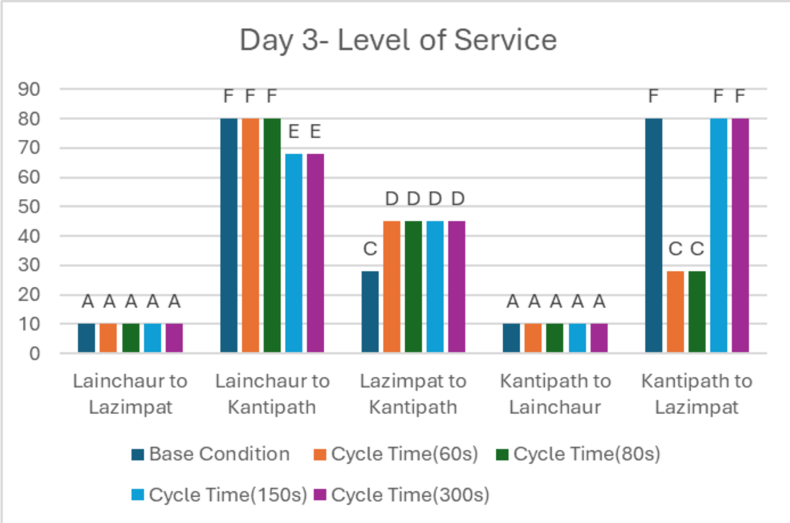

FIGURE 12. Level of Service Comparison under Different Signal Cycle Time Scenarios (Day 3)

8. FUTURE PERFORMANCE ASSESSMENT

A 7% increase in traffic demand was applied in VISSIM to examine future performance using Day 1 as the base condition. The results show poorer traffic operation, mainly on the approaches that are already congested. Lainchaur– Kantipath remains at LOS F, with increases in queue length and delay. Kantipath–Lazimpat also remains at LOS F and shows higher queue length and delay, as shown in Figure 13.

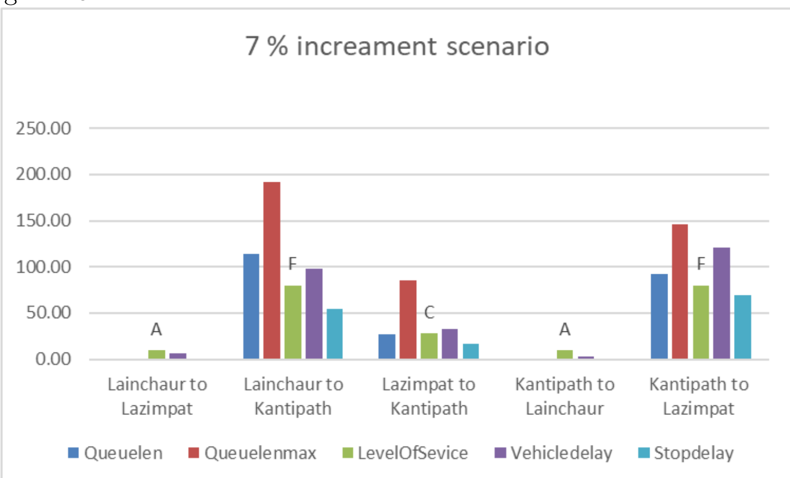

FIGURE 13. Traffic Performance under 7% Increased Demand Scenario

The Lainchaur–Lazimpat and Kantipath–Lainchaur movements remain at LOS A, while Lazimpat–Kantipath remains at LOS C with only a small change. At the intersection level, average delay increases and the overall system remains at LOS D, close to capacity, as shown in

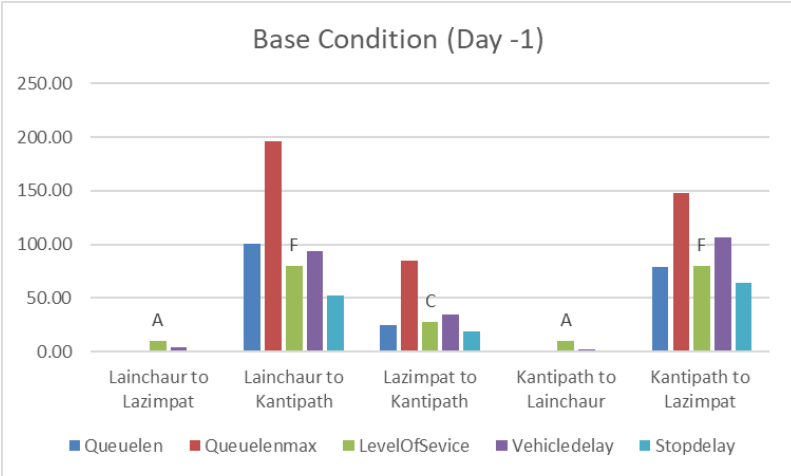

Figure 14.

FIGURE 14. Traffic Performance under 7% Increased Demand Scenario

Overall, the 7% increase in traffic demand worsens congestion on the critical approaches. The results suggest that the existing fixed-time signal control is not sufficient for the future demand. Therefore, an adaptive or automated signal system is recommended for improving the performance of the intersection.

9. RESULTS AND CONCLUSIONS

PTV VISSIM was used to evaluate the operational performance of Lainchaur Intersection using peak-hour data from 9:00 AM–11:00 AM. Motorcycles make up 76.5% of the traffic stream, showing that the intersection has maximum traffic volume of two wheelers. Since the intersection has a variable vehicle composition, different driving behaviour was also assessed.

The Webster method gives a flow ratio greater than 1, indicating oversaturated condition in the intersection during peak hours. The Lainchaur– Kantipath and Kantipath–Lazimpat routes operate at LOS F with long queues and high delays, while the other paths operate between LOS A and C. This shows that traffic demand is unevenly distributed among the different routes.

Fixed-time signal control performs better than manual control in the tested cases, but its performance changes when traffic demand changes. This indicates limited flexibility. With a 7% increase in traffic demand, both delays and queues become longer, showing that the intersection is sensitive to increase in demand. The intersection is already oversaturated , and fixed time control alone is not sufficient. Adaptive signal control and improved lane discipline are therefore suggested to improve its operation.

10. RECOMMENDATIONS

Because of limited right-of-way and dense roadside development, major geometric changes such as lane widening, additional turning lanes, or grade separation are not practical at Lainchaur Intersection. Movement restrictions and class-specific lanes are also not feasible solutions because of the heterogeneous traffic. The analysis shows that the intersection is already oversaturated, and future traffic growth will further worse the delays and queue lengths. Although fixed-time signal control provides some improvement, it cannot respond well to changes in traffic demand.

Therefore, an actuated signal control system is recommended. It can adjust signal timing according to real time traffic demand effectively. This can help to minimize delay and improve intersection performance. Considering the existing physical constraints, actuated control is considered the most practical solution.

11. FUTURE SCOPES

Because of the existing physical constraints at Lainchaur Intersection, future improvements should mainly focus on traffic operation and signal control rather than major geometric changes. Actuated signal control is one possible approach because it can adjust signal timing according to traffic demand.

Further improvement could be achieved by combining actuated control with adaptive signal systems and traffic sensors as part of an Intelligent Transport System (ITS). This would allow the signal to respond more effectively to changes in traffic flow and could improve LOS. Signal coordination with nearby intersections could also be considered. Corridor-based signal management may help maintain more continuous traffic flow and reduce delays across the network.

12. ACKNOWLEDGEMENT

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